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BIOLOGICAL CLOCKS AND SHIFT WORK SCHEDULING

REPORT

PREPARED BY THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

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August 30, 1983

LETTER OF TRANSMITTAL

Honorable Don Fuqua, Chairman
Committee on Science and Technology
U. S. House of Representatives
Washington, D.C. 20515

Dear Chairman Fuqua:

I am pleased to transmit a report of the Subcommittee on Investigations and Oversight's investigation of biological clocks and shift work scheduling. The report is the result of an extensive review on that subject by the Subcommittee and hearings held on March 23 and 24, 1983.

Because of the potential of circadian rhythms research to improve worker health, safety, and productivity, the Subcommittee conducted this review. Today, because of the need to have around-the-clock operations, 20 million Americans, in industries as diverse as manufacturing, health care, police, and other emergency services are employed on rotating shifts. Since many employees find night shifts undesirable, systems of shift rotation have evolved to insure fairness in scheduling. Since many shift rotations alter sleep patterns or interrupt other natural circadian rhythms of the human body, shift schedules can contribute to physical, psychological, and social problems for workers, productive problems for management, and safety and health problems for the general public who depend on the performance of shift workers. Symptoms related to "circadian desynchronization" are familiar to air travelers who suffer from "jet lag".

Recently, published scientific studies have suggested that shift work schedules which are based on circadian principles could substantially improve worker morale and productivity and generally lessen the adverse impact of shift rotation.

The Subcommittee believes this report will be useful to workers, managers, and public officials both as an impetus to designing shift work rotations and as a springboard to further research and experimentation with shift work schedules.

The report addresses two audiences and presents conclusions and recommendations for each.

(1) With regard to the private sector, we recommend that both labor and management utilize the findings of biological clocks research to design and implement new shift work schedules that would reduce workers' problems and improve worker productivity. The report focuses attention on the problem and suggests a general approach to its solution. No changes are indicated for existing legislation that governs work hours or compensation.

(2) In the case of government agencies, we find that there is a significant public safety issue regarding reduced alertness and job performance in certain critical occupations under Federal regulatory jurisdiction. We recommend (a) that additional research be undertaken to determine whether on-the-job vigilance and judgment are degraded as a result of biological clock desynchronization from disruptive work schedules in jobs such as air traffic control and nuclear powerplant operation, and (b) if so, that Federal agencies responsible for regulating these occupations formulate scientifically designed work schedule guidelines to minimize or eliminate the problems identified.

I would like to express my appreciation to Dr. Phillip G. Sokolove (Congressional Science Fellow sponsored by the Federation of American Societies for Experimental Biology) for assistance in helping the Subcommittee to organize the hearings and to prepare this report, and to Mary Jane Bolle, Labor Economics analyst with CRS for an excellent summary of the hearings.

Sincerely,

Albert Gore, Jr.

Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

CONTENTS

	Page
I. Introduction	1
II. Summary of Findings and Recommendations	2
III. Discussion of Findings	4
IV. Discussion of Recommendations	20
V. Appendices	25
A. Witness List	25
B. Gore/Skeen correspondence with FAA	28
C. Gore/Skeen correspondence with NRC	34

I. INTRODUCTION

Today, 20 million Americans, or about one out of every five workers, is employed on a rotating shift. In many industries where round-the-clock coverage is needed, including health care, public services, and manufacturing, two or three full-time shifts of workers are employed each day. Since many employees find evening and night shifts undesirable, various systems of shift rotation have evolved in part, to insure fairness in scheduling. To the extent that shift rotation alters sleep patterns or interrupts other natural, circadian[1] rhythms of the human body, it can contribute to physical, psychological, and social problems for workers, productivity problems for management, and safety and health problems for the general public.

The problems experienced by rotating shift workers are not unlike problems associated with "jet lag". As in the case of a jet traveler who has flown across multiple time zones, the shift worker must cope with a sudden change in sleep/wake schedules every time he rotates to a new shift. Because virtually all physiological functions of the body are controlled by internal biological clocks which require a number of days to reset, the worker's natural body rhythms become desynchronized with each shift rotation. As a result the worker can experience a variety of problems including chronic insomnia and fatigue, inability to concentrate, gastrointestinal upset, extreme irritability and loss of alertness. Not surprisingly such symptoms can lead to increased worker absenteeism and turnover, and reduced productivity. In addition, reduced vigilance and alertness can result in more severe industrial accidents and, for some occupations, could place the public at risk due to errors of inattention.

Generally, the Subcommittee considered two questions:

1) What is the current state of scientific understanding regarding daily (e.g. circadian) biological rhythms and what are its implications for productivity, health, and safety?

2) Are efforts in the public and private sector being made to apply scientific knowledge of biological clocks to the design of work schedules that can improve worker health and productivity and reduce potential threats to public safety?

The report summarizes the issues and viewpoints offered at the hearings held on March 23 and 24, 1983 and contains the finding and recommendations of the Subcommittee.

A list of witnesses at the hearing appears at Appendix A.

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[1]Circadian means approximately 24 hours, and comes from the Latin term "circa diem," meaning "around a day."

II. SUMMARY OF FINDINGS AND RECOMMENDATIONS

I. Issue: What is known about human biological clocks and to what extent can results of basic research on circadian rhythms be applied to improve industrial productivity, worker health and job satisfaction, and public safety?

Findings:

1) Basic research has shown that humans possess biological clocks that time a number of periodic physiological processes including sleep-wake cycles and body temperature-alertness, with a natural period of about 25 hours. Research indicates that these clocks take a number of days to reset and can be reset more easily in the "forward" than the "backward" direction.

2) Insomnia, fatigue, and loss of alertness associated with rotating or highly irregular work schedules present significant problems for management such as a negative impact on productivity and could potentially compromise public health and safety in occupations such as police work, nursing, airline piloting, and nuclear power plant operation.

3) A recent applications-oriented circadian rhythms study showed that a scientifically designed rotation schedule was instrumental in improving worker health, job satisfaction, turnover, and productivity. The fundamental circadian principles followed in designing the experimental schedule were (1) to rotate shifts in a 'forward' direction -- that is to later, rather than to earlier starting times and (2) to allow as much time as possible between successive rotations.

II. Issue: To what extent have labor, management, and the Federal Government become aware of and utilized basic research findings on biological clocks in designing and implementing biologically compatible shift rotation schedules?

Findings:

1) Rotating shift schedules are employed where economic and other factors dictate 24-hour a day, seven day a week operation, but where full staffing of evening and night shifts on a voluntary basis is impossible or undesirable. Although schedules vary widely, workers commonly rotate between three shifts -- night, evening, and day -- on approximately a weekly basis. Overall, industrial shift rotation schedules have not been designed on the basis of scientific principles.

2) Many Federal agencies employ rotating shift workers or have regulatory responsibility for health and safety in industries where shift workers are employed. Generally, managers in federal agencies are not aware of the practical implications of biological clocks research, and even when aware, they have not generally made use of the results of such research in developing

rules or guidelines for scheduling shift workers under their jurisdiction.

3) Like most other Federal agencies, the Federal Aviation Administration (FAA) and the Nuclear Regulatory Commission (NRC) do not apply circadian principles in shift work scheduling of air traffic controllers and nuclear power plant operators, respectively.

a) The FAA considers worker preference to be a primary factor in determining shift rotation schedules of air traffic controllers. It does not use circadian principles to schedule shift rotations. Substantial questions are raised in the hearing record as to whether studies conducted by the FAA to monitor controller stress due to circadian disruption adequately assess decrements in alertness, vigilance, and job performance resulting from work schedule-related circadian desynchronization.

b) The NRC does not currently use circadian principles to schedule shift rotations at nuclear power plants. Following to the March 1979 nuclear power plant accident at Three Mile Island (TMI), the NRC formed a Human Factors Division that is considering, among other issues, the impact of circadian disruption from shift work on the safety of nuclear power plant operation.

Recommendations:

1) For their mutual benefit, labor and management should study further the implications of circadian research and, where appropriate, employ fundamental circadian principles in developing cooperative agreements on the scheduling of rotating shifts. These principles suggest that:

- Workers should rotate to later rather than to earlier shifts (e.g., from day-to-evening-to-night shifts rather than the reverse.)

- Adequate time (nominally three weeks or more) should be provided between shift rotations to allow body clocks to resynchronize to the new shift.

2) Similarly federal agencies should conduct additional research on circadian disynchronization and, where appropriate should apply circadian principles in determining shift work schedules in order to improve the productivity, health, and safety of federal workers and others within the jurisdiction of federal regulatory programs. Specific Subcommittee recommendations are made to the Federal Aviation Administration and the Nuclear Regulatory Commission (see p. 26). More general recommendations are made to the National Institutes of Health and the National Institute of Occupational Safety and Health (see p. 27).

29-312 O - 84 - 2

III. DISCUSSION OF FINDINGS

I. Issue: What is known about human biological clocks and to what extent can results of basic research on circadian rhythms be applied to improve industrial productivity, worker health and job satisfaction, and public safety?

Findings:

1) Basic research has shown that humans possess biological clocks that time a number of periodic physiological processes including sleep-wake cycles and body temperature-alertness, with a natural period of about 25 hours. Research indicates that these clocks take a number of days to reset and can be reset more easily in the "forward" than the "backward" direction.

Human Biological Clocks

Humans, like all living organisms, possess internal, biological clocks that have evolved in response to our 24-hour environment. These clocks time virtually every aspect of our physiology and behavior, including cycles of sleep and wakefulness, blood hormones, and body temperature. For example, they begin to warm up our bodies before we wake in the morning and start the release of various hormones in preparation for the day ahead.[2]

In humans the clock governing sleep and wakefulness is a dense cluster of nerve cells in the brain that oscillates with a period of about 25 hours in the absence of external timing cues. Normally this 25-hour pacemaker is reset every day to a 24-hour cycle by the daily light/dark cycle.[3] A second clock that times the body temperature rhythm and circadian rhythms of alertness and performance[4] is more difficult to reset. Thus, after a flight across multiple time zones, the timing of sleep can adjust relatively rapidly, but the daily cycle of alertness takes much longer to adapt. The precise anatomical location has not yet been pinpointed.[5]

Because of the 25-hour period of our internal clocks, and our tendency to drift to a later schedule each day, our clocks can be reset much more easily to a later time than to an earlier

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[2]"Biological Clocks and Shift Work Scheduling", Hearings before the Subcommittee on Investigations and Oversight, Committee on Science and Technology, U. S. House of Representatives, March 23 and 24, 1983, Serial No. 7, (Hereinafter referred to as Hearings) at 235-236.
[3]Ibid., at 235-236 and 222-223 (Czeisler).
[4]Ibid., at 225-226 (Czeisler).
[5]Ibid., at 236-237 (Moore-Ede).

time. For example, researchers in West Germany have found that on a westbound trip across six time zones, a person's rhythm of psychomotor performance takes four days to adjust. After eastbound flights across six time zones, a person takes eight to ten days to resynchronize.[6]

Scientists have learned that there are ways to help in resetting our internal time clocks. External cues that reset the clocks biologically are called "zeitgabers." Bright light approaching the intensity of sunlight, for example, is a zeitgaber. Other zeitgabers are coffee, alcohol, and some drugs. Social cues such as those which come from being around other people and food availability are also zeitgabers. The strength of the zeitgabers favoring day-oriented schedules can result in rapid loss of nocturnal orientation for night shift workers.[7]

This new knowledge about human biological clocks has taught researchers that humans cannot adjust their bodies at will. Therefore, they have concluded that shift schedules, especially shift rotation schedules, should be designed to accommodate the body's natural rhythms. Because human biological clocks naturally cause the body's physiological rhythms to drift to later bedtimes and waking times, the body can adjust more quickly if the direction of the shift rotation is "clockwise", from morning to evening to night shifts.[8]

Researchers have also learned that the frequency of shift rotation is an important factor in the ability to adjust to shift schedule changes. Because body clocks are desynchronized for many days after a shift change, fewer physiological problems arise if shift changes are scheduled to occur less often, i.e., the more time allowed between shift changes, the more completely the body clocks can adjust to the new shift.[9]

Circadian Rhythms and Job Performance

Among the more important findings of basic biological clocks research from a practical standpoint is the relation between circadian rhythms and human performance. Evidence presented at the hearings established that performance varies with time of day. In particular, it has been shown that major decrements in performance usually occur at the low point of the daily cycle of body temperature at around 5:00 to 7:00 a.m. each day.[10] Data

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[6]Moore-Ede, "Sleeping as the World Turns," Natural History, V.91, October 1982, p. 62., Hearings supra note 2 at 246.
[7]Hearings supra note 2 at 327-328 (Ehret) and 227-228 (Czeisler).
[8]Ibid., at 174 and 221-222 (Czeisler).
[9]Ibid., at 229 (Gore and Czeisler). See also Czeisler et. al., "Rotating Shift Work Schedules that Disrupt Sleep are Improved by Applying Circadian Principles, Science; V.217, July 30, 1982, pp. 1264-1267, Hearings supra note 2 at 201.

illustrating this point was presented for errors of sonar operators[11] and trucking accidents.[12]

Studies with particularly disturbing implications for occupations associated with monotonous monitoring of sophisticated equipment were also described. In one case brain waves and eye blinks were continuously monitored during night driving on an expressway. The records indicated that nap episodes of up to 20 minutes occurred while the vehicle was moving down the highway.[13] Similar observations were also cited in a Swedish study of high speed train operators during night runs.[14] Apparently, when temperature and performance are at their low points, the body can appear to be awake and functional at some low level, while the brain is actually asleep.

According to the testimony presented to the Subcommittee, studies such as these have not been conducted for workers in critical jobs such as airline piloting and nuclear powerplant operation for fear of the liabilities involved if people were to be found to be "napping" at work.[15] The few field studies that have been conducted concluded that performance on simple tasks and low memory load exercises varies directly with body temperature and results in poor night shift performance in such activities as answering a switchboard, tying threads, reading meters, and interpreting characters on a screen.[16] As body temperature cycles adjust to new time schedules, night shift performance improves.

Finding:

2) Insomnia, fatigue, and loss of alertness associated with rotating or highly irregular work schedules present significant problems for management, such as a negative impact on productivity and could potentially compromise public health and safety in occupations such as police work, nursing, airline piloting, and nuclear power plant operation.

In their testimony rotating shift workers consistently

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[10] Hearings supra note 2 at 171 (Czeisler) and U. S. National Academy of Sciences, "Sleep, Biological Clocks and Health", Health and Behavior: A Report of the Institute of Medicine, U. S. National Academy of Sciences, National Academy Press, Washington, D.C., 1982, p. 112, Hearings supra note 2 at 193.
[11] Hearings supra note 2 at 171 (Czeisler).
[12] Ibid., at 172.
[13] Ibid., at 173.
[14] Id.
[15] Ibid., at 231.
[16] Monk, Timothy H., Ph.D., Institute of Chronobiology, New York Hospital, Cornell Medical Center. European Shiftwork Research. Unsolicited testimony, p. 9, Hearings supra note 2 Appendix at 398.

identified physiological, psychological, and social problems that they attributed to their schedules. These included chronic insomnia and fatigue, gastrointestinal disorders, increased use of drugs, social isolation, increased domestic stress, difficulty concentrating, loss of alertness, increased anxiety, and lack of initiative.

Testimony presented at the hearings also indicated that insomnia, fatigue, and loss of alertness associated with rotating or highly irregular work schedules present significant problems for management and can potentially compromise public health and safety in occupations such as police work, nursing, and airline piloting, and nuclear power plant operation.

Labor's Problems with Shift Work

Insomnia and Fatigue -- Insomnia and fragmented sleep are common to shift workers. Fatigue on the job tends to be more or less constant for workers on the night shift. For example, one witness testified that he had "seen workers go to sleep standing up while operating a piece of equipment."[17] In a police survey, 49 percent of sampled officers reported that fatigue was a particular problem between the third and eighth consecutive nights. Also, fatigue emerging from sleep disturbances was found to be most pronounced in workers who were performing boring routine activities or any form of mental work.[18]

Physiological Illness -- Stomach and digestive disorders are also frequent problems among shift workers. Testimony indicated that workers have trouble deciding what and when to eat, especially when rotating onto the night shift.[19] They have complained of loss of appetite and even loss of taste. In one study, 28 percent of sampled police officers on rotating shifts reported digestive problems.[20] Another study of 128 shift workers found a 2- to 4-fold increase in the incidence of gastrointestinal disorders -- peptic ulcers, disrupted eating habits, etc. -- in rotating shift workers.[21]

Evidence from Scandinavia indicates that shift workers may also suffer increased cardio-vascular risks.[22] Other researchers have observed that immunological resistance to disease appears weakened, colds increase, and aging seems accelerated.[23]

Personal and Emotional Problems -- Stress in the family life

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[17] Hearings supra note 2 at 4 (Thompson).
[18] Ibid., at 309 (Goldstein).
[19] Ibid., at 165 (Neilsen).
[20] Ibid., at 309 (Goldstein).
[21] U. S. National Academy of Sciences, op. cit., Hearings supra note 2 at 197.
[22] Hearings supra note 2 at 183 (Czeisler).
[23] Ibid., at 309 (Goldstein).

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of shift workers is reportedly manifested in more frequent interpersonal conflicts, a higher divorce rate among shift workers, lack of family activity on weekends, and fewer friends, most of whom are tied to work. The stresses and problems of rotating shift work were, for one witness who is now on a fixed shift, so great he would have quit his job rather than return to a rotating schedule.[24] This was echoed by the report of a police officer who found it physically impossible to remain on a rotating schedule and was forced to retire.[25]

Emotional disturbances tend to go hand-in-hand with stress. A stress survey among police officers found general anxiety, sexual dysfunction, headaches, and muscle tension frequent among rotating shift workers. Many of these symptoms can be grouped under the heading "night worker neurosis," which includes but is not limited to general physical weakness, insomnia despite fatigue and self-reported personality changes.[26] The latter tend to be characterized by low frustration tolerance, high irritability, impulsivity, and aggression.

Use of Drugs -- Rotating shift workers tend to have a higher rate of drug use, especially alcohol, caffeine, and sleeping pills. Typical self-medication, for example, involves massive doses of caffeine when a worker needs to be awake, even though he is tired; followed by massive doses of alcohol and/or sleeping pills to sedate and depress the central nervous system when a worker knows he needs to sleep even though his body is awake.[27] With this high rate of drug use comes the danger of increased mortality from suicide or accidental overdose, as well as increased costs from treatment for nonfatal overdose emergencies, increased crime because of addiction and increased safety hazards from persons operating machinery or driving while under the influence of sleep medication.[28]

Reduced Alertness -- Loss of alertness is another problem facing rotating shift workers. Sleepiness and reduced alertness on the job were cited by a police witness as factors that can contribute to less effective law enforcement and can present a potential hazard to others from officers operating motor vehicles on routine patrol.[29] A nursing representative noted that medication errors, equipment failures, and errors in judgment were most apt to occur at the low point of a nurse's daily cycle.[30] An airline pilot voiced concern that flight schedules which disrupted natural sleep-wake cycles were probably a

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[24] Ibid., at 5 (Thompson).
[25] Ibid., at 304 (Goldstein).
[26] Ibid., at 310 (Goldstein).
[27] Ibid., at 310-311 (Goldstein).
[28] U. S. National Academy of Sciences, op. cit., Hearings supra note 2 at 193.
[29] Hearings supra note 2 at 10 (Day).
[30] Ibid., at 14-15 (Jones).

contributing factor in a number of air carrier accidents.[31] A nuclear power plant operator testified that extra effort was needed to stay awake and alert during early morning hours[32] -- a period that corresponds, possibly significantly to the time of the nuclear accident at Three Mile Island.[33]

Management Problems with Shift Rotation

With shift rotations have come a number of problems for management; one is the accident rate. Studies have shown that while the difference in accident rates between shifts is small, (that is, the number of accidents relative to the number of workers is about the same) the seriousness of accidents occurring on night shifts is significantly greater than on day or afternoon shifts.[34]

Worker turnover is another problem. For example, on U. S. Navy submarines where sailors work an 18-hour day, 6 hours on and 12 hours off, turnover averages 33 to 50 percent per voyage, and only a small number sign up for more than 2 or 3 of the 90-day submarine missions.[35] In addition, managers of shift workers are faced with elevated levels of worker inefficiency and absenteeism (police workers on rotating shift patterns, for example, tend to be absent most frequently on the first day of work after rotating off the night shift).[36]

Legal liability on the part of the company for worker errors which are brought on by rotating shift work and which affect the public is another problem facing managers. The public tends to expect certain groups serving it to respond with split-second decisionmaking in high stress situations such as those in which a deadly weapon may be used; and to respond with judgment, reasoning, and accuracy, despite the debilitating effects of night and rotating shift work.

Most managers understand that rotating shifts are undesirable, but very few industry planners and schedulers are familiar with research findings from which both they and workers could benefit.

If current shift rotation schedules are undesirable because they result in many physical, psychological, and social problems for workers, then such schedules are also likely to have a

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[31] Ibid., at 23-24; 141-142 (Stone).
[32] Ibid., at 133 (Pollack).
[33] U. S. National Academy of Sciences, op. cit., Hearings supra note 2 at 199.
[34] Zalusky, "Shiftwork -- A complex of Problems", AFL-CIO Federationist, V. 85, May 1978, Hearings supra note 2 at 274.
[35] Moore-Ede, "Sleeping as the World Turns", op. cit., Hearings supra note 2 at 246.
[36] Hearings supra note 2 at 310 (Goldstein).

significant, negative effect on productivity. Conversely, if there were a simple and relative inexpensive means to modify rotation schedules so as to reduce worker discomfort and dissatisfaction, one might expect significant gains in productivity as a consequence. Recent results of biological clocks research suggest just such an approach.

Finding:

3) A recent applications-oriented circadian rhythms study showed that a scientifically designed rotation schedule was instrumental in improving worker health, job satisfaction, turnover, and productivity. The fundamental circadian principles followed in designing the experimental schedule were (1) to rotate shifts in a 'forward' direction -- that is to later, rather than to earlier starting times and (2) to allow as much time as possible between successive rotations.

Field studies of industrial shift schedules designed to implement knowledge gained from circadian rhythms research are to the knowledge of the Subcommittee virtually non-existant. A notable exception is a recent experiment conducted at Great Salt Lake Minerals and Chemicals Corporation (GSL) which was reported in Science magazine.[37] Hearing witnesses on one panel included the plant production manager, Mr. Preston Richey; an hourly foreman, Mr. Scott Nielsen; and one of the scientists who participated in the study, Dr. Charles Czeisler.

Prior to late 1980, employees at GSL worked a rotating schedule in which they changed from night-to-evening-to-day shifts on a roughly weekly basis. Employee complaints of physiological and personal problems associated with the rotating schedule led plant management to contact Dr. Czeisler and his colleagues (Dr. M. Moore-Ede and Dr. R. Coleman) to help redesign the shift schedule.

According to Dr. Czeisler, the concepts that he and others had developed in laboratory research on human circadian rhythms were used to change the shift schedule to one that made more biological sense. Specifically, the direction of rotation was reversed to a day-evening-night pattern, and the time between rotations was increased from one to three weeks. At the same time, educational sessions for management and workers were held to explain the need for and basic rationale behind these changes.

Before the change, 90 percent of the workers complained that the schedule changed too often, and nearly 70 percent reported moderate to severe sleep problems with most taking half a week or longer to adjust their sleep time after a rotation. After the change, almost three-quarters of the workers said they preferred the new direction of rotation, and over a quarter noted a

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[37]Czeisler, et al., op. cit., Hearings supra note 2 at 201-204.

distinct improvement in their general health.[38]

An hourly foreman at GSL, Mr. Scott Neilsen, testified that he and his co-workers found they had more time on the new schedule to do the things they wanted besides eat, sleep, and work, because they had more chance to get used to a shift. He also noted that plant morale was higher and that there were fewer interpersonal conflicts on the new schedule.[39]

Productivity (the rate of potash harvesting at the plant) rose substantially on the new schedule as compared on a quarterly basis with the previous two years. A rise of 12 percent in the first quarter after the schedule change was followed in the second quarter by a 22 percent rise, and a 32 percent rise in the third quarter.[40]

The plant production manager, Mr. Preston Richey, noted that GSL was sold on the concept of matching shift schedules to fundamental circadian rhythms. "The changes made were not particularly dramatic, but the results were."[41]

In discussing the implications of the GSL study, Dr. Czeisler pointed out the encouraging results indicated that the application of circadian principles to the workplace could be very productive even at this early stage in our understanding of biological clocks mechanisms. He also cautioned, however, that further applications research was badly needed, since the specific GSL schedule would not necessarily be equally effective in other settings. "We still have the training wheels on the bicycle, and a lot more research needs to be done in order to further improve these kinds of schedules."[42]

The application of circadian principles require that specific schedules be developed for each workplace. While the present research results are valid in establishing (a) that these principles can have significant positive effects and (b) that there are potential dangers in ignoring circadian desynchronosis, the precise GSL schedule may be impractical for all situations. For example, an agency or business may employ 4 or 5 shifts rather than just 3 so that the terms "day", "evening", and "night" shift would not apply precisely. However, the direction of rotation should still be "clockwise".

II. Issue: To what extent have labor, management, and the Federal Government become aware of and utilized basic research findings on biological clocks in designing and implementing biologically compatible shift rotation schedules?

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[38] Hearings supra note 2 at 174 (Czeisler).
[39] Ibid., at 166-67 (Neilson).
[40] Ibid., at 174 (Czeisler).
[41] Ibid., at 162 (Richey).
[42] Ibid., at 175 (Czeisler).

Findings:

1) Rotating shift schedules are employed where economic and other factors dictate 24-hour a day, seven day a week operation, but where full staffing of evening and night shifts on a voluntary basis is impossible or undesirable. Although schedules vary widely, workers commonly rotate between three shifts -- night, evening, and day -- on approximately a weekly basis. Overall, industrial shift rotation schedules have not been designed on the basis of scientific principles.

Shiftwork and Labor-Mangement Bargaining

Extent of Rotating Shiftwork

Rotating shift schedules are extensively employed in a wide variety of private and public sector occupations that require staffing 24 hours a day, seven days a week. Estimates of the number of U. S. workers on rotating shifts differ, but it is clear that a substantial fraction of the workforce is on some form of rotating shift schedule.

According to the National Center for Health Statistics, an estimated 20 percent of all U. S. workers are employed in rotating shifts -- about 27 percent of all men aged 20 through 64, and 16 percent of all women in this age group.[43] The Bureau of Labor Statistics estimates that approximately 16 percent of the total workforce, or about one in six U. S. employees is employed on rotating shifts.[44]

The proportion of workers on rotating shifts varies considerably from industry to industry, and from one geographic region of the country to another. In some major industries, more than one-half of all workers are on rotation shifts.[45] For example, shift workers constitute about 53 percent of all workers in synthetic textile mills, 48 percent in basic iron and steel, 46 percent in pulp paper mills, 35 percent in industrial chemicals, 35 percent in motor vehicle parts, and 32 percent in petroleum refining.[46]

Nationwide statistics on specific rotation schedules are virtually impossible to obtain.[47] Two workers testified they

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[43]These people answered yes to the question, "Does your job involve a variable work shift? That is, do you work the day shift sometimes and the night shift at other times?" Hearings supra note 2 at 184.
[44]Hearings supra note 2 at 272-273 (Zalusky).
[45]U.S. National Academy of Sciences, op. cit., Hearings supra note 2 at 193.
[46]Zalusky, op. cit., Hearings supra note 2 at 275.
[47]Hearings supra note 2 at 288 (Ward).

encountered identical rotation schedules at their respective plants, -- night-to-evening-to-day shift on an approximately weekly basis -- and this same weekly schedule was claimed by Dr. Czeisler to be the most common one is use in America.[48] The manager of Great Salt Lake Minerals cited results of an informal survey of other managers that phoned him for more information on the specifics of the GSL experiment. Among his callers, weekly or approximately weekly rotation in the "backward" direction (night-evening-day) was found to be traditional in more than half of the businesses.[49]

A number of other schedules were described in the course of the hearings. These included rotation between 12 hour shifts,[50] bi-weekly rotation between day and evening shifts followed by a single week on the night shift,[51] and a rapid rotation pattern (similar to many European schedules) consisting of two days on evenings, two days on days, and one day on the night shift.[52]

Reasons for Rotating Shifts

Since the turn of the century, in response to accelerating demand to keep foundries and factories going around the clock, shift work has proliferated at the estimated rate of six percent per decade.[53] Extra shifts have resulted among other reasons from (1) increased demand for goods being produced, coupled with too-small existing plant capacity; (2) the need to maximize the use of expensive or capital-intensive production resources for quick capital recovery and to take advantage of the fact that the costs of capital relative to labor were increasing; (3) the desire to take advantage of lower off peak-hour utility rates; (4) requirements for round-the-clock coverage by police, fire, hospital, transportation, or public utility services; (5) maintenance of services (restaurants, grocery stores, drug stores, gas stations, etc.) for the benefit of the public; (6) a desire to make maximum use of daylight hours for purposes of reducing costs, increasing efficiency, or meeting deadlines (for example on construction projects); (7) the need to keep expensive process or manufacturing equipment in continual operation to avoid costly and time consuming startup operation; and (8) a need to save time or make more money, as in the case of truck drivers carrying perishable items or otherwise anxious to complete a run.[54]

With an increasing demand for around-the-clock coverage more people must work night shifts than will normally volunteer for

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[48] Ibid., at 221 (Gore, Czeisler, and Neilsen).
[49] Ibid., at 230 (Richey).
[50] Ibid., at 314 (LeClercq).
[51] Ibid., at 358 (Reighard).
[52] Id.
[53] Ibid., at 288 (Ward).
[54] Ibid., at 272 (Zalusky); & 299 (Ward).

night duty. As a result, management has devised various systems of shift rotation to insure: (1) that workers will not have to spend the rest of their lives sleeping during daylight hours; (2) that younger, less experienced workers will not all be clustered onto the night shift (as might happen when permanent shifts are selected on the basis of seniority); and (3) that those being groomed for management will have opportunities to work all three shifts in order to understand the problems inherent in each.[55]

Generally, American workers deal with the issue of shift work scheduling and rotation through collective bargaining. According to the Bureau of Labor Statistics, 80 percent of major collective bargaining agreements in 1975 included some reference to shift work. These agreements addressed the issues of worker shift selection based on length of service with the employer, premium pay for shift work, pay differentials among various shifts, the sequence of shift rotation, the frequency of shift changes, the number of crews, and hours of rest.[56]

Although one witness testified that collective bargaining was facilitated by awareness of scientific knowledge which is available for practical application,[57] he pointed out that new studies are needed to give labor and management insight about the best type of shift design for particular community and industrial settings.[58] He also noted that since the mid-seventies NIOSH research costs on shiftwork studies totalled only $400,000, and he urged that special funds -- on the order of $1.5 million to $2 million spread over three to four years -- be allocated for additional NIOSH research and practical strategies to deal with shiftwork.[59]

The call for additional applications-oriented research on shiftwork was echoed by an industrial engineer who stated that industry planners knew very little about research findings that might benefit them directly.[60] He agreed that the problems of shiftwork were generally treated as necessary evils that were compensated with higher pay, [61] and he suggested that a gap exists with regard to circadian rhythm research directed at the American worker.[62]

In the United States no laws deal specifically with shift work. However, the Fair Labor Standards Act (FLSA),[63] the Walsh-Healey Act,[64] and the Work-Hours Contract Act[65] have an

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[55] Ibid., at 293-294 (Ward).
[56] Ibid., at 273 (Zalusky); & Zalusky, op. cit. at 274.
[57] Hearings supra note 2 at 285 (Zalusky).
[58] Ibid., at 296.
[59] Ibid., at 286.
[60] Ibid., at 289 & 296 (Ward).
[61] Ibid., at 296-297 (Gore).
[62] Ibid., at 289 (Ward).
[63] 29 U.S.C. 201 et. seq.

impact on shift work scheduling since they regulate minimum wages and maximum hours of workers employed in various types of work. Thus, for example the FLSA, requires that higher wages be paid for overtime above 40 hours per week so that it is generally less expensive for management to add additional shifts to provide additional coverage.[66]

2) In preparation for these hearings, the Subcommittee on Investigations and Oversight obtained information from over four dozen federal agencies and bureaus on the use of rotating shifts. The information obtained supports the conclusion that many Federal agencies employ rotating shift workers or have regulatory responsibility for health and safety in industries where shift workers are employed. Also managers in federal agencies generally are not aware of the practical implications of biological clocks research, and even when aware, they have not generally made use of the results of such research in developing rules or guidelines for scheduling shift workers under their jurisdiction.

Finding:

(3) Like most other federal agencies, the Federal Aviation Administration (FAA) and the Nuclear Regulatory Commission (NRC) do not apply circadian principles in shift work scheduling of air traffic controllers and nuclear power plant operators, respectively.

a) The FAA considers worker preference a primary factor in determining shift rotation schedules of air traffic controllers. It does not use circadian principles to schedule shift rotations. Substantial questions are raised in the hearing record as to whether studies conducted by the FAA to monitor controller stress due to circadian disruption adequately assesses decrements in alertness, vigilance, and job performance resulting from work schedule-related circadian desynchronization.

Air traffic controllers work two basic rotation schedules: the "straight 5" (evening shift for two weeks; day shift two weeks; night shift one week) and the "2-2-1" or "rattler" (evening shift two days; day shift two days; night shift 9 or 10 hours after the last day shift). Controllers reportedly prefer the 2-2-1 schedule because it offers the most consecutive times off duty -- 80 hours off between work weeks.[67]

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[64]41 U.S.C. 35 et. seq.
[65]5 U.S.C. 673(c); 28 U.S.C. 1499; 40 U.S.C. 327 et. seq.
[66]For a more complete discussion of the impact of federal labor laws on shift work, see Zalusky, op. cit., Hearings supra note 2 at 274.
[67]Hearings supra note 2 at 358-359 (Reighard).

Dr. Reighard, Federal Flight Surgeon, testified that biochemical and physiological studies indicated no increased stress from the 2-2-1 schedule, no medical or scientific evidence that one shift is better than another and no evidence of diminished work performance associated with a specific shift.[68] Because of these findings, the FAA has allowed controller shift scheduling decisions to be made at the facility level and has encouraged worker input in the absence of any other nationwide guidelines: "Our research tells us that worker participation in developing the work schedule -- and not the type of schedule itself -- is the key factor in fostering worker satisfaction and a productive work environment."[69]

The effect of this policy is that controllers tend to choose a schedule that provides the most time off duty at the end of the work week -- i.e., the 2-2-1. Subcommittee Members expressed reservations about FAA use of worker preference to dictate rotation schedules:

> "Mr. REID... it seems to me that when we are dealing with something as important as the safety of the flying public, the leisure time of the air traffic controller should be a secondary consideration.[70]

A number of FAA positions are contrary to scientific testimony presented at the hearings:

- Scientific evidence indicates that poor rotation schedules can disrupt circadian rhythms and thereby potentially compromise performance. Nevertheless, the FAA maintains that nothing in its own data on circadian effects has relevance to actual performance, efficiency or effectiveness in air traffic control.[71]

- FAA witnesses testified that electroencephalographic (EEG) recordings provide the best means of measuring alertness levels. Nevertheless, they noted that technical problems preclude the use of this method on air traffic controllers.[72]

  As a result, the FAA has not to the Subcommittee's knowledge carried out objective testing for on-the-job alertness.

- FAA schedules have not attempted to determine the least biologically disruptive schedules from among a number of alternatives. Instead, the FAA has only compared the

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[68] Ibid., at 259.
[69] Ibid., at 359.
[70] Ibid., at 372 (Reid).
[71] Ibid., at 371;378 (Reighard).
[72] Ibid., at 373; 378-79 (Melton).

physiological effects of two current schedules, and both can be judged unsatisfactory from a scientific point of view.[73]

In summary, the FAA, although admittedly having a longstanding interest in "the potential for circadian ... desynchronosis,"[74] has failed to find any evidence linking schedule-related circadian disruption with decrements in worker performance and alertness. Although the Civil Air Medical Institute (CAMI) has reportedly investigated the effects of altering sleep and time schedules using sophisticated methods,[75] Dr. Reighard insisted that no studies found anything pointing to a need to change current air controller work schedules, and no detrimental effects could be found on "productivity, efficiency, [or] performance ..."[76]

Pilots, in contrast to air traffic controllers, do not work regularly rotating schedules. They do, however, have irregular schedules, decided by the airline companies to facilitate passenger scheduling and carrier availability. They may also fly across multiple time zones. As a result of both of these factors, air schedules of pilots can conflict with their normal body rhythms. Nevertheless, Dr. Reighart denied that schedule-induced fatigue was a factor in air carrier accidents. In conflict with this position, representatives from the Air Line Pilots Association (ALPA) cited National Transportation Safety Board (NTSB) accident reports which indicated that fatigue had been a factor in a number of airplane crashes.[77]

Finally, of some concern to the Subcommittee was the fact that the FAA apparently does not consult its medical personnel in setting up changes in flight schedule rules. When Dr. Reighard was asked whether he had been consulted in the recent rulemaking on flight-time/duty-time regulations, he responded that although there had been informal discussions "at various times over the years," he "did not officially coordinate [the rulemaking] nor was [his] coordination sought."[78]

b) The NRC does not currently use circadian principles to schedule shift rotations at nuclear power plants. Following the March 1979 nuclear power plant accident at Three Mile Island (TMI), the NRC formed

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[73] Ibid., at 380 (Gore). See also Mr. Rheem's comments, at 377.
[74] Ibid., at 358 (Reighard).
[75] Ibid., at 378.
[76] Ibid., at 371. See also the exchange of correspondence between Chairman Gore and Congressman Skeen, and Lynn Helms, FAA Administrator, contained in Appendix B to this report.
[77] Hearings supra note 2 at 23-24 (Stone).
[78] Ibid., at 387 (Reighard).

a Human Factors Division that is considering, among other issues, the impact of circadian disruption from shift work on the safety of nuclear power plant operation.

Mr. Hugh Thompson of the Nuclear Regulatory Commission (NRC) indicated that the Commission was currently aware of the potential for problems of circadian rhythm disruption resulting from shift work. He indicated that this awareness stemmed from the accident at Three Mile Island (TMI).[79]

Following the accident at TMI, the NRC created the Division of Human Factors Safety to study the effect of human factors on nuclear power plant safety. In addition to control room design, staffing, operator qualifications, and training, one of the division's concerns is shift scheduling. Operator complaints drew the Human Factors division to focus attention on work hours.[80] This attention, in turn, led the NRC to focus on such resultant factors as absenteeism, turnover, and job satisfaction -- factors that the industry had not, in the past, kept records on.

A new study on the impact of shift scheduling, to be conducted by the Human Affairs Research Center of the Pacific National Laboratories, will further examine these factors.[81] However, no "actual research type measurements" will be made and no biological factors will be studied by the Pacific National Laboratories.[82] Thus, in spite of NRC's concern, the agency plans to sponsor no new research in the area of job vigilance as a function of shift or time of day. The Research Department of the NRC will develop data only if the current literature review proves inadequate to meet its needs.[83]

NRC work scheduling guidelines (contained in NRC Generic Letter 82-12, June 15, 1982) do "not lay down any specific guidance for the shift schedule itself."[84] Instead, the guidelines set certain limits on the total amount of time an operator can work within a one, two, or seven-day period. They stipulate that no more than 16 hours can be worked straight, and they restrict the use of overtime.[85]

Two plants in the power industry (not nuclear) have been experimenting with 12-hour shifts as an alternative to eight-hour rotating shifts. Although workers have been

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[79] Ibid., at 361; 374; 386 (Thompson).
[80] Ibid., at 375.
[81] Ibid., at 362.
[82] Ibid., at 375-376.
[83] Ibid., at 377 (Jones).
[84] Ibid., at 362 (Thompson).
[85] Id.

enthusiastic,[86] some studies indicate that 12-hour shifts may pose a potential safety risk, because vigilance declines steadily over eight hours and then remains low for the next four hours.[87]

Overall, the NRC appeared interested in and aware of the problems and effects of biological rhythms and shift scheduling.

Research on shift work, sleep patterns, and biological rhythms has been approached from various perspectives in the past by a few federal agencies other than the FAA and NRC. The Department of Defense, for example, has examined the effects of jet lag on performance of Rapid Deployment Forces, airplane flight crews and submarine personnel. Human biological clocks research has also been utilized by NASA in setting sleep-wake schedules in manned spaceflight operations. General concerns about the effects of shift work schedules on human health and performance led NIOSH to sponsor major symposia on this topic in 1975 and again in 1979.[88]

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[86] Ibid., at 363.
[87] Ibid., at 385 (Jones).
[88] Those wishing a comprehensive treatment of scientific research on the subject of biological clocks and the health and performance effects of various work-sleep schedules are urged to consult the report of the second NIOSH symposium. NIOSH Proceedings, The Twenty-four Hour Workday: Proceedings of a Symposium on Variations in Work-Sleep Schedules. (L.C. Johnson, et al., editors). DHHS (NIOSH) Publication No. 81-127.

IV. DISCUSSION OF RECOMMENDATIONS

Based on its findings, the Subcommittee recommends that:

1. For their mutual benefit, labor and management should study further the implications of circadian research and, where appropriate, employ fundamental circadian principles in developing cooperative agreements on the scheduling of rotating shifts. These principles suggest that:

   - Workers should rotate to later rather than to earlier shifts (e.g., from day-to-evening-to-night shifts rather than the reverse).

   - Adequate time (nominally three weeks or more) should be provided between shift rotations to allow body clocks to resynchronize to the new shift.

Circadian principles should be evaluated by labor and management in the design of rotating shift schedules.

The testimony presented at these hearings indicates that potentially, substantial benefits could accrue to both labor and management if circadian rhythm principles were integrated into the design of rotating shift schedules. Among the potential benefits for workers are greater job satisfaction, less irritability, better sleep, fewer health problems and improved home life. Management could also potentially realize gains from higher productivity, fewer health complaints, improved worker morale, and lower rates of absenteeism. One witness characterized this as a "win-win" situation.[89]

The scientific principles arising from basic research on human circadian rhythms are simple, but some understanding of the basis for these principles is necessary so that adjustments can be made for specific situations. No one schedule is likely to be ideal for all situations, nor is it necessary to view all present schedules as "bad." The fundamental properties of human biological clocks that apply most directly to shift rotation are (1) human rhythms have a natural period of longer than 24 hours; (2) they can be more easily shifted to later rather than to earlier times, and (3) readjustment (or resetting) after a time shift is not immediate, but requires a number of days for complete synchronization to a new schedule. Given these findings, two general rules for rotating shift design are easily appreciated:

- Rotation schedules should accommodate the natural tendency of human biological clocks to reset more

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[89] Hearings supra note 2, at 330 (Ehret).

readily to later times. Thus, workers should rotate from day-to-evening-to-night shifts rather than in the reverse direction.

- The time between successive rotations should be as long as possible. Frequent shift changes should be avoided. Workers should remain on a given shift three weeks or more before moving to a new shift to allow time for rephasing of workers' biological rhythms.

Education and Training of Management and Workers

An element crucial to the success of scientific shift program implementation is the laying of a proper educational foundation. The objective of such education should be not only to provide a background for negotiating changes in work schedules, but also to provide a basis for adjustment of family and social lifestyles to be more compatible with the body's natural rhythms. Both workers and management require an adequate understanding of biological rhythms in order to appreciate the need for change and to understand the rationale for the types of changes that are likely to be required.

- Attention should be directed at developing and implementing educational programs or training modules that can aid both workers and management in understanding biological clocks and appreciating their implications for work schedule design.

- Workers and management also need to become informed about the need to accommodate leisure time activities as well as work schedules to the body's natural rhythms. With proper education, eating and sleeping habits and timing of leisure activities can be used to aid in adjusting body rhythms to abrupt shift changes.

2. Similarly, federal agencies should conduct additional research on circadian disynchronization and, where appropriate, should apply circadian principles in determining shift work schedules in order to improve the productivity, health, and safety of federal workers and others within the jurisdiction of federal regulatory programs. Specific Subcommittee recommendations are made to the Federal Aviation Administration and the Nuclear Regulatory Commission. More general recommendations are made to the National Institutes of Health and the National Institute of Occupational Safety and Health.

Managers within federal agencies where shift work is scheduled on a rotating basis should become familiar with biological rhythms research and its implications for worker well-being and productivity. Whenever possible the same general principles set out in Recommendation #1, above, should be applied to rotating schedule design. The Subcommittee has specific recommendations for four federal agencies: FAA, NRC, NIOSH, and

NIH.

A. Recommendations for the Federal Aviation Administration

The recommendations specified in #1, above, are applicable to agencies and commissions having regulatory responsibilities for setting work schedule guidelines to protect public health and safety. The hearing record is striking in the contrast it provides between attitudes of the NRC and the FAA with regard to the importance of biological rhythms in determining work schedules. NRC recognizes that a potential safety issue is involved in the conflict between natural biological rhythms and traditional shift rotation schedules, while FAA reports its studies show that no problem exists. The Subcommittee, therefore, makes the following specific recommendations for the FAA:

- The FAA should develop technology-based methods to monitor operational, on-the-job alertness, vigilance, and overall performance in individual air traffic controllers as a function of time of day.

- Studies using these methods should compare the effects of existing shift rotation schedules and other, non-traditional schedules (such as extended length or straight shifts) on the parameters (alertness, etc.) noted above.

- The FAA should give due consideration to objective factors in developing shift work scheduling guidelines and to the extent scientific application studies of circadian principles support the need for or benefits from shift schedules based on fundamental circadian principles, the FAA should develop guidelines for such schedules for air traffic controllers. The agency should also incorporate these principles into its recommendations for airline pilot and crew flight-time duty-time rules.

B. Recommendations for the Nuclear Regulatory Commission

Although the NRC currently has underway a study on shift scheduling and its implication for nuclear power plant safety, the Subcommittee notes that this study will not involve operational measurements of vigilance and alertness in nuclear power plant operators. The Subcommittee therefore recommends that:

- The NRC undertake such measurements as soon as possible in order to consider the appropriateness of developing uniform guidelines for shift scheduling in the nuclear power industry.[90]

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[90] In response to this recommendation, which was made to the NRC in
(Footnote continued)

C. Recommendation for the National Institute of Occupational Safety and Health

The National Institute of Occupational Safety and Health (NIOSH) should support research and experimentation to establish the types of shift schedules most appropriate to different occupational and industrial settings.

Any attempt to design and implement new rotation schedules that are more compatible with workers' biological clocks may face a number of hurdles. Foremost may be lack of knowledge about what the "ideal" schedule should be for a given industrial or occupational setting. The half dozen or so workplace studies carried out to date are consistent in identifying common problems of biologically inappropriate work schedules, but not enough case studies have been carried out to suggest schedules that are both economically and practically feasible. As far as the Subcommittee can determine, the GSL experiment represents the only time an entire plant has been involved in a controlled study applying scientific principles for shift work scheduling.

More studies are needed in which both management and labor are willing to participate. Although general biological guidelines for shift scheduling are fairly clear, specific scheduling details need to be worked out on a case-by-case basis and then implemented in an atmosphere of mutual cooperation.

Comparisons between rapid rotation schedules (those with one or two days between rotations) and slow rotations schedules (those with intervals of three or more weeks between rotations) are especially needed. Because of the importance to workers and management generally, because of concerns about federal shift workers, and because of the federal responsibility for maintaining and promoting public health and safety in certain specific industries subject to federal regulation. The Subcommittee recommends that NIOSH initiate such studies, perhaps on an interagency basis with affected agencies.

D. Recommendation for National Institutes of Health

Basic research on biological clocks which is essential to provide new information on the biomedical implications of, and potential treatments for circadian rhythm disruption should continue to be supported by the National Institutes of Health.

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[90] (continued)
a letter dated August 17, 1983, the NRC agreed to undertake such studies. See Appendix C.

At the basic research level, we need to know more about the location of biological clocks that time different physiological rhythms, and we need to learn more about the environmental timing cues that can affect them.

Also, we need to know more about the types of biomedical problems that can directly or indirectly be attributed to frequent shift changes. For example, sleepiness, fatigue and digestive disorders are commonly encountered difficulties, but research at National Institute of Mental Health suggests that affective mental disorders such as depression may also be triggered or exacerbated by shift work.[91]

Finally, we need research in a number of other areas related to or impacting on biological clocks and shift work scheduling, including the following:

- Research to determine the physical and mental disorders that arise as a consequence of frequent shift rotation.
- Human isolation studies to define more precisely the relation between sleep/wake cycles and other physiological and behavioral circadian rhythms.
- Biomedical research to develop more efficient methods of rephasing the biological clock -- possibly with zeitgabers such as drugs, diet, or special lighting -- in order to minimize or avoid the body's negative response to abrupt shift changes.

The Subcommittee strongly supports the need for such studies and believes that NIH (and DOD where appropriate) should continue to foster and expand these and related investigations.

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[91] Hearings supra note 2, at 255 (Wehr).

APPENDIX A - WITNESS LIST

Wednesday, March 23, 1983

Panel 1 - Shift Workers

Mr. Gordon Thompson, Employee
Bridgestone Tire Company
Route 2, Box 120
Carthage, Tennessee 37030

Mr. Kerry Day, Police Officer
Prince George's County Police Department
5012 Rhode Island Avenue
College Park, Maryland

Jeanne M. Jones, Registered Nurse
American Nurses Association
Vice President for Nursing Services
Cumberland Medical Center
Crossville, Tennessee

Captain Richard Stone, Airline Pilot
Air Line Pilots Association
1625 Massachusetts Avenue, N.W.
Washington, D.C. 20036

Mr. Frank Pollack, Nuclear Reactor Operator
Commonwealth Edison Quad Cities Plant
2236 Avalon Court
Bettendorf, Iowa 52722

Panel 2 - Case Study

Mr. Preston Richey, Production Manager
Great Salt Lake Minerals and Chemical Corporation
Box 1190
Ogden, Utah 84402

Scott N. Nielsen, Hourly Employee
Great Salt Lake Minerals and Chemical Corporation
Ogden, Utah 84402

Dr. Charles A. Czeisler, Director
Center for Design of Industrial Schedules
50 Staniford Street
No. 800
Boston, Massachusetts 02144
and
Assistant Professor of Medicine

Division of Health Policy Research & Education
Harvard University
Cambridge, Massachusetts 02138

Panel 3 - Biological Rhythms Research

Dr. Thomas A. Wehr, Acting Chief
Clinical Psychology Branch
National Institute of Mental Health
Building 10, 4S239
Bethesda, Maryland 20205

Dr. Martin C. Moore-Ede, Professor
Department of Physiology and Biophysics
Harvard Medical School
Boston, Massachusetts 02115

Thursday, March 24, 1983

Panel 1 - Current Practices

Mr. John L. Zalusky, Economist
AFL-CIO
815 16th Street, N.W.
Washington, D.C. 20006

Dr. Richard Ward, Professor
Department of Industrial Engineering
West Virginia University
Morgantown, West Virginia 26506

Panel 2 - New Initiatives and Future Perspectives

Dr. Harvey Goldstein, Director
Psychological Services
Prince George's County Police Department
14544 Elm Street
Upper Marlboro, Maryland 20772

Dr. Gary R. LeClercq, Medical Director
Exxon Chemical Americas
P. O. Box 3272
Houston, Texas 77001

Accompanied by:

Dr. Gary Krieger, Baytown Area Medical Director
Exxon Chemical Americas

Dr. Charles F. Ehret, Senior Scientist
Division of Biological and Medical Research
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Panel 3 - Federal Agencies

Dr. H. L. Rieghard
Federal Air Surgeon
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

Hugh Thompson, Director
Division of Human Factors Safety
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

APPENDIX 8

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

April 26, 1983

Honorable J. Lynn Helms
Administrator
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

Dear Mr. Helms:

On March 23 and 24, 1983, the Investigations and Oversight Subcommittee held hearings on the subject of biological clocks and shift work. Dr. H. Reichard, FAA Flight Surgeon, testified at the hearing about flight controller shift schedules.

While the Subcommittee has not yet completed its report, the testimony presented at the hearings by Dr. Reichard and others leads us at this time to make the two following requests of the FAA:

(1) that the FAA consider changes in the rules governing air traffic controller work schedules and undertake additional studies to define parameters for measuring variations in on-the-job vigilance by air traffic controllers, and

(2) that the FAA include at least one recognized expert in human circadian physiology on its proposed advisory commission to evaluate airline crew flight and duty time scheduling.

Although the hearings were not intended to explore in depth the issue of airline flight crew flight-time/duty-time schedules, much of the testimony was related directly or indirectly to this subject. Many of the "fatique" problems encountered by flight crews with highly irregular work schedules are similar in nature to those expressed by other workers on rotating shifts who testified at the hearing. The preliminary data on circadian rhythms research supports the hypothesis that such "fatique" problems arise because work schedules conflict with the workers' natural, biological (circadian) rhythms.

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Workers such as nurses, police, airline pilots and nuclear power plant operators who are responsible for the health and safety of others, can place both themselves and others at risk if forced by their work schedules to perform at times when they are unlikely to be able to function at peak efficiency. Testimony presented at the hearing by scientists who have conducted human isolation studies seems to confirm that alertness, cognitive performance and a variety of psychophysical parameters vary with an approximately 24 hour cycle that parallels the circadian cycle in core body temperature. Thus, workers in any occupation could be expected to be less vigilant and more error-prone at certain times than at others. For critical occupations it is of particular importance that circadian research be considered when designing work schedules. In the specific case of airline flight personnel conclusions consistent with this view were reached by a workshop on this topic organized by NASA in response to a Congressional mandate (see attached summary of NASA Technical Memorandum 81275).

On the basis of the testimony, we believe that the FAA should consider changes in the rules and guidelines governing air traffic controller work schedules based on the new data coming out of the circadian research efforts. Dr. Reichard's testimony indicated that controller work schedules were established primarily on the basis of the controllers' preferences. While it may be a worthy goal to permit air traffic controllers some latitude in choosing their own work schedules (such as the 2-2-1 "rattler") that maximize the number of consecutive hours off per week, we are sure you will agree that the issue of air safety must outweigh considerations of worker preference. Any work rotation schedule that has the potential of reducing controller vigilance and alertness (especially on the midnight shift) should be viewed as unsatisfactory from a safety standpoint. Testimony from other witnesses suggest that current controller work schedules are those most likely to produce problems.

Although the FAA has conducted numerous studies to measure physiological variables and total sleep time in traffic controllers on different rotation schedules, such measures alone may not be adequate to determine potential performance deficits due to sleepiness or loss of alertness. Subjective reports of sleepiness and fatigue are also probably inadequate. Research cited at the hearings shows individuals can be unaware of sleep-like lapses in attention that may last as long as 20 minutes.

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In light of the testimony received at the hearings, it is likely that the final report will recommend that the FAA consult with outside as well as in-house experts to design studies that define parameters for measuring temporal variations in on-the-job vigilance in controllers so that the resulting data, if appropriate, can be used to design and implement new shift rotation schedules that minimize reductions in vigilance. The Subcommittee will be happy to provide a copy of the hearing transcript for your further information.

We understand that the FAA is considering the establishment of an advisory commission to recommend changes in the rules governing airline crew flight and duty time schedules. Given the nature of the evidence presented to the Subcommittee along with earlier recommendations of the FAA's own scientists (see publication AM69-17, p. 9), it would seem appropriate to include on such a commission at least one recognized expert in human circadian physiology. We would appreciate receiving additional information on your plans to establish such a commission and a list of potential members.

We look forward to your reply. If you have any questions, please contact Robert B. Nicholas, Chief Counsel/Staff Director, or Phil Sokolove of the Subcommittee at 226-3636.

Sincerely,

Albert Gore, Jr.
Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

Joe Skeen
Joe Skeen
Ranking Minority Member
Subcommittee on Investigations
and Oversight

AG:Stk

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U.S. Department of Transportation
Federal Aviation Administration

Office of the Administrator

800 Independence Ave., S.W.
Washington, D.C. 20591

MAY 27 1983

The Honorable Albert Gore, Jr.
Chairman, Subcommittee on Investigations
and Oversight
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

Thank you for your recent letter following up on the hearing before the Subcommittee on Investigations and Oversight concerning the impact of circadian rhythm on shift workers.

In your letter, you recommended "that the FAA consider changes in the rules governing air traffic controller work schedules and undertake additional studies to define parameters for measuring variations in on-the-job vigilance by air traffic controllers." While I appreciate this suggestion, I am unwilling to direct such a change in employees' shift schedules absent indications that safety warrants such a change. Evidence developed by the FAA to date indicates that, apart from the requirement of matching staffing to anticipated traffic, the most important aspect of developing our shift schedules in the FAA is to solicit and consider employee input. This is a key element of my human relations program in the FAA--providing employees a meaningful opportunity to shape the environment in which they work. You may be assured that I will not hesitate to take whatever action is necessary in the interest of aviation safety; however, we have no indication of any derogation of safety related to FAA shift scheduling practices. Therefore, it would be contrary to my objective of promoting effective human relations in the FAA to force FAA employees to undergo shift changes for theoretical reasons that have not been substantiated in the FAA.

In terms of your recommendation that we undertake studies to develop a program to measure controller vigilance, we have such an effort underway at the present time. This program is designed to enable us to monitor controller performance so that potential errors can be caught before they become serious.

You have also recommended that the FAA appoint a recognized expert in human circadian physiology to the advisory group that

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will seek to establish a regulatory proposal for flight and duty time. I am enclosing a copy of the FAA's notice proposing the establishment of the advisory group. You will note that we have proposed representatives from the types of aviation organizations who would be affected most by any rule change, along with a representative of an aviation consumer group. I believe this type of committee lends itself best to resolving the longstanding issues of flight and duty time if we include parties that are most interested in and directly affected by a rule change. Naturally, any of the groups represented on the committee may consult whatever sources they want in advancing the position they may wish to take during the regulatory negotiation process. Further, any proposal provided to me would have to go through the normal rulemaking processes before it could be made effective, thus offering a full opportunity for complete input from any source.

Thanks again for writing me on this subject. I look forward to the receipt of the Committee report on circadian rhythm, and you may be assured we will carefully review its content and recommendations.

Sincerely,

(signed) J. Lynn Helms

J. Lynn Helms
Administrator

Enclosure

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1. Report No. NASA TM 81275	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Pilot Fatigue and Circadian Desynchronosis*		5. Report Date 6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No. A-8528
9. Performing Organization Name and Address Ames Research Center, NASA Moffett Field, California 94035		10. Work Unit No. 505-35-21 11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum 14. Sponsoring Agency Code

15. Supplementary Notes

*Report of a Workshop held in San Francisco, California, on August 26-28, 1980

16. Abstract

A workshop on pilot fatigue and circadian desynchronosis was sponsored by the Man-Vehicle Systems Research Division at Ames Research Center in August 1980. The workshop was designed to elicit the opinions of experts with regard to whether circadian desynchronosis is a significant problem in air transport flying, the magnitude of the problem, and possible ways to approach it from a research viewpoint. Workshop participants included scientists from universities, military and other government laboratories, and aviation operations specialists from the airline industry and air carrier pilots.

It was concluded that there is a safety problem, of uncertain magnitude, due to transmeridian flying and a potential problem due to fatigue in association with various factors found in air transport operations. Much information is already available in the scientific literature, but there is a clear need to "translate" this information into terms meaningful to line flight personnel. The participants agreed on a need for better, hopefully objective data regarding the sleep, activity and other pertinent factors from pilots flying a variety of demanding schedules. Simulation studies of flight crew performance should be utilized to determine the degree of fatigue induced by demanding schedules. Further simulation studies should be performed to delineate more precisely the factors responsible for performance decrements in flight and to test solutions proposed to resolve problems induced by fatigue and desynchronosis.

17. Key Words (Suggested by Author(s))	18. Distribution Statement		
Fatigue Pilot fatigue Crew fatigue Performance Circadian Dysrhythmia	Unlimited STAR Category - 03		
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Appendix C

U.S. HOUSE OF REPRESENTATIVES
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Minority Staff Director

August 17, 1983

Nunzio J. Palladino, Chairman
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Palladino:

We are writing to call your attention to the enclosed excerpt from Report 98-103, part 2 that accompanied the Nuclear Regulatory Commission Authorization Bill (H.R. 2510). The report encourages the NRC to support scientific studies on the relationship between rotating shiftwork schedules and deterioration in nuclear power plant operator performance. Based on information obtained in hearings before the Investigations and Oversight Subcommittee of the Committee on Science and Technology, we concur fully in this recommendation.

On March 23 and 24, 1983, oversight hearings were held that explored the issue of possible conflicts between rotating shiftwork schedules and human biological clocks. The Nuclear Regulatory Commission was asked to testify at the hearings regarding the impact of biological clocks research findings on shift scheduling in the nuclear power plant industry. Of particular concern to the Subcommittee was the possibility that improperly designed shiftwork schedules might adversely affect nuclear power plant operator performance due to jet-lag type symptoms which include fatigue, loss of alertness, and increased chance of mental errors.

The Subcommittee was pleased to learn from Mr. Hugh Thompson of the Human Factors Division that the NRC was both aware of the scientific issues involved and was concerned about the possible threat to public health and safety that could result from work-schedule related operator errors. We believe the NRC should be commended for its willingness to address important human factors problems in dealing with nuclear power plant safety. However, we think it is also important to recognize that there still appears to be too little scientific data on circadian rhythms of direct practical relevance to regulatory decision making.

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A need clearly exists for studies of the type recommended in the Report language. In particular, objective measurements of operator vigilance, alertness, and decision making need to be made under actual or simulated control room conditions to assess the effects of various alternative work schedules and shift rotations on operational performance. In view of the immediate, practical utility of the results for regulatory purposes, we would urge the NRC to undertake such research as soon as possible. We look forward to hearing from you about the current position of the NRC regarding this subject.

Thank you for your attention to this matter.

Sincerely,

Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

Joe Skeen
Ranking Minority Member
Subcommittee on Investigations
and Oversight

AG/Stk

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98TH CONGRESS | HOUSE OF REPRESENTATIVES | REPT. 98-103
1st Session | Part 2

NUCLEAR REGULATORY COMMISSION AUTHORIZATIONS FOR FISCAL YEARS 1984 AND 1985

JUNE 24, 1983.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

---

Mr. DINGELL, from the Committee on Energy and Commerce, submitted the following

REPORT

Together with

ADDITIONAL VIEWS

[To accompany H.R. 2510]

[Including cost estimate of the Congressional Budget Office]

The Committee on Energy and Commerce, to whom was referred the bill (H.R. 2510) to authorize appropriations to the Nuclear Regulatory Commission in accordance with section 261 of the Atomic Energy Act of 1954 and section 305 of the Energy Reorganization Act of 1974, and for other purposes, having considered the same, report favorably thereon with an amendment and recommend that the bill as amended do pass.

The amendment (stated in terms of the page and line numbers of the bill as reported by the Committee on Interior and Insular Affairs) is as follows:

Page 12, after line 20, insert the following:

> SEC. 9. Of the amounts authorized to be appropriated pursuant to section 1, during the fiscal years 1984 and 1985, the Nuclear Regulatory Commission may use such sums as may be necessary to issue temporary operating licenses for utilization facilities required to be licensed under section 103 or 104 of the Atomic Energy Act of 1954. Such temporary operating licenses shall be issued in the same manner and subject to the same requirements as provided in section 192 of the Atomic Energy Act of 1954,

	Actual fiscal year 1982		Estimate fiscal year 1983		Estimate fiscal year 1984		Estimate fiscal year 1985	
	Dollars	People	Dollars	People	Dollars	People	Dollars	People
Operating reactors	10,808	218	11,341	290	9,034	306	9,021	312
Systematic safety evaluation of operating reactors	2,035	42	1,599	36	4,766	34	5,166	42
Operating licensing	4,434	16	4,736	33	4,840	43	3,863	44
Casework	15,011	297	11,739	207	8,745	178	6,895	146
Safety technology	8,507	106	11,490	116	11,005	113	9,735	112
TMI-2 cleanup	230	17	315	17	0	7	0	7
Management direction and support	82	42	0	49	0	49	0	46
Total	41,107	738	41,220	748	38,390	730	34,680	709

The programs conducted under the Nuclear Reactor Regulation function are the review of applications for construction permits, operating licenses and license amendments. The Office of Nuclear Reactor Regulation is also responsible for resolution of unresolved safety issues, generic issues and the implementation of the human factors program.

The Committee notes that human factors research is essential to maintain and improve the safe operation of nuclear power plants, and it commends the NRC on its attention to this important area. However, adequate resources have yet to be devoted to developing criteria for measuring changes in nuclear power plant operator performance and vigilance as a function of work schedule, time of day, or other environmental conditions. Prior recommendations have been made to the NRC by outside experts regarding the high priority need for research on these problems (see report NUREG/CR-2833), and testimony at recent hearings before another Committee established that scientific studies are badly needed on the relationship between rotating shift work schedules and deterioration in operator performance. The Committee strongly urges the NRC to conduct research as a part of its human factors program on the effects of work schedules and other environmental factors on operator performance and alertness as measured under real or realistically simulated nuclear power plant control room conditions.

The bill as reported by the Committee approves the NRR funding level requested by the Commission for fiscal years 1984 and 1985. The bill provides specific instructions, however, with regard to the use of funds authorized for gas-cooled thermal reactors, the Clinch River breeder reactor project, phase III of the systematic evaluation program, and implementation of the Commission's regionalization plan and the issuance of temporary operating licenses. The conditions imposed by the Committee are discussed elsewhere in this report.

Office of Inspection and Enforcement.—The NRC has requested a total authorization of $70,910,000 for fiscal year 1984 and $74,770,000 for fiscal year 1985 for the salaries and expenses of the Office of Inspection and Enforcement [I&E].

A comparative summary of I&E's estimated budget requirements for fiscal years 1982, 1983, 1984, and 1985 appears in the table below.

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
CHAIRMAN

September 22, 1983

The Honorable Albert Gore, Jr., Chairman
Subcommittee on Investigations and Oversight
Committee on Science and Technology
United States House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

This letter is in response to your letter of August 17, 1983 urging NRC to undertake additional research on the effects of work schedules and shift rotations on operational performance as a part of its Human Factors Program.

As Mr. Hugh Thompson, Director, Division of Human Factors Safety stated at the Oversight Hearings on March 23 and 24, 1983, NRC has developed an integrated Human Factors Program Plan. One of the twenty-four subelements in that plan is "Guidance on Limits and Conditions of Shift Work." As part of that effort, we have received a draft contractor report evaluating the experience of other industries similar to the nuclear industry with regard to shift arrangements and shift rotations. That study indicated that while there is a relationship between safety performance and shift scheduling practices, the applicability of these experiences to the nuclear industry is limited because of differences in on-the-job performance requirements. Moreover, the majority of these studies focused on job satisfaction with safety performance as a secondary effect. A future task in this subelement includes a program for evaluating the effects of shift duration, shift schedule arrangements and shift rotation on operator performance.

We are currently reviewing alternative methods for collecting the necessary data to determine the need for any regulatory actions. A method will be selected in the near future that we believe will be technically feasible and within resource constraints. Surveys, case studies, and limited use of control rooms or simulators are among the methods being considered.

The staff has assigned this subelement activity a medium priority in comparison to other subelements in the Human Factors Program Plan in large part because shift work is more often noted as an operator job satisfaction issue rather than a direct safety issue.

Conducting an expanded research program, which would provide objective measurements of operator performance as suggested in your letter, though possibly desirable, is beyond the current scope of our research plans and resources. To conduct this type of research the services of a representative sample of trained reactor operators would be required over an extended period of time. The dedication of existing training simulators to a scientific research effort would interrupt critical operator training programs. Since

there is a current industry-wide shortage of trained nuclear power plant operators, such a program would probably place an undue burden upon the nuclear industry. This interruption could have an undesirable impact on safety. Thus, we believe that a more limited approach for developing the technical basis for possible regulatory changes, regarding shift scheduling and shift rotation, is feasible and appropriate at this time. In the future, as the staffing and simulator situation is eased, more empirical research may be feasible. In the interim, as the Human Factors Program Plan indicates, efforts will be pursued to develop objective job performance measures.

NRC will, of course, continue to evaluate licensee performance and if significant safety issues related to shift scheduling are identified, we will take appropriate regulatory action to protect the public health and safety.

Sincerely,

Nunzio Palladino

Nunzio J. Palladino
Chairman

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